Performance of Seedigated and Conventionally Planted Crops

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Applied Engineering in Agriculture. 7(2): 170-176. (1991)

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Abstract

Seedigation is the use of a moving sprinkler irrigation system to broadcast seeds on the soil surface. Seed germination, plant characteristics and yield for grain sorghum, winter wheat and soybeans that were seedigated and conventionally planted are compared. When the seeding rates for seedigation were increased above that for conventional planting, and adequate moisture was available for germination, grain sorghum and wheat seedigated on tilled surfaces produced yields similar to conventionally planted crops. Seedigation of soybeans into fallow conditions, or when used as a relay crop, was unsuccessful. Shallow disking following seedigation did not improve germination or yield of grain sorghum or winter wheat. Using seedigation to plant wheat into soybeans offers good potential. Seedigating wheat into dense grain sorghum canopies was less successful. **KEYWORDS**. Irrigation, Center pivots, Seeder, Germination.

Introduction

Center pivot irrigation equipment can perform tasks in addition to irrigating crops. Using the center pivot to apply pesticides and fertilizers has become widely accepted. Equipment recently has been developed to utilize center pivot irrigation systems to plant crops. This practice is called seedigation. Seedigation offers several advantages to conventional planting. For example, it may be possible to seedigate annual crops during wet periods, which provides a longer growing season than conventional planting after the soil dries.

Planting a new crop into an existing crop, relay cropping, is a potential application of seedigation. In contrast to double cropping, which involves planting two crops in succession in the same field in the same growing season, relay cropping provides a longer growing season, and potentially more forage and grain production. The longer growing season is critical where the frost-free period restricts double cropping. Relay cropping has advantages of potentially a second cash crop, livestock forage production, reduced soil erosion, and uptake of water and nitrogen that might leach into the ground water.

Article was submitted for publication in February 1990; reviewed and approved for publication by the Soil and Water Div. of ASAE in September 1990.

Contribution from the Nebraska Agricultural Experiment Station, Lincoln. Published with the approval of the Director as Journal Series No. 9153, Agricultural Research Division, University of Nebraska.

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Seedigation with a center pivot provides irrigators additional management options. However, little information is available on seedigation. In this article, we compare the effectiveness of seedigation to conventional planting and relay cropping for a rotation of grain sorghum, hard-red winter wheat and soybeans. Specifically, we had three objectives. The first study compared the performance of conventionally planted crops to those planted using seedigation. The second objective was to determine if incorporation of seeds following seedigation on fallow soil improved germination and yield. The final test compared yields for annual and relay cropping.

Background

Little research on seedigation has been reported. However, research on surface seeding using aerial or broadcast methods provides some results that may apply to seedigation.

The success of surface seeding is difficult to predict. In Great Britain, winter cereal yields consistently decreased with increasing amount of residue (Graham et al., 1986). The lowest yields were attained when the previous crops straw was chopped and spread over the soil surface. Francis and Deloughery (1986) discovered that increasing the amount of surface residue consistently reduced the germination of corn, grain sorghum and wheat during a greenhouse study. However, Clapp (1974) interseeded wheat into soybeans in the coastal plains of North Carolina. Wheat yields were equal to conventionally planted crops and exceeded yields of double cropped wheat that was planted after the soybeans were harvested. Lamm (1981) aerially seeded wheat into growing grain sorghum and alternately, grain sorghum into growing wheat, and produced acceptable yields. Guenzi et al. (1967) showed that grain sorghum residue can possess phytotoxic substances that reduce the yield of susceptible relay crops. Triplett et al. (1976) surveyed Ohio farmers who aerially seeded soybeans into wheat. Sixty percent of the trials failed with an average yield of 0.54 Mg/ha (8 bushels/acre).

One of the most consistent outcomes of surface seeding is that the seeding rate must be increased above that for conventional methods. Watts and Fink (1969) recommended that the seeding rate for surface seeding soybeans be increased by 0.07 Mg/ha (1 bu/ac) over that for conventional methods. Francis and Deloughery (1986) found that the seeding rate should be 30% higher than for conventional planting of corn, grain sorghum and soybeans. Evidently, when seeds are not incorporated in the soil, germination and seedling survival are lower than for conventional planting.

Precipitation following seeding has been a major factor in determining the success of surface seeding. Broadcast soybeans did not emerge well on a Tuscumbia clay loam when the soil was hard and dry (Whisler et al., 1977). When precipitation at planting was above normal, broadcast soybeans yielded similar to conventionally planted soybeans. Crops seedigated with moving irrigation systems could be irrigated following seedigation. Once roots have penetrated the soil, watering is not as critical according to Threadgill (1987). Threadgill (1987) suggested that corn and sorghum seeds be irrigated for the first five days or more following seedigation and for ten or more days following seedigation of soybeans. The ability to control soil-water through seedigation and subsequent irrigation may improve the reliability of relay cropping.

Success with seedigation may depend on the condition of the soil surface and the presence of a growing crop or crop residues. The impact of the falling seed and localized erosion around the seed may improve seed-soil contact when seedigating onto a freshly tilled soil. For example, Nace (1986) seedigated wheat onto a residue-free soil and obtained similar germination rates and yields as conventionally drilled wheat. Residue or a crop canopy may help the seeds from reaching the soil resulting in less germination or seedling survival. Conversely, a crop canopy and residue cover may maintain a humid seed environment that promotes germination.

Previous research with surface seeding, and limited studies on seedigation, have produced mixed results. Crop residue and canopy cover, as well as rain or irrigation after seeding, appear to be determining factors. Usually, the seeding rate must be increased above that for conventional planting. Numerous questions still remain about seedigation for annual and relay crops.

Methods and Procedures

To investigate the potential for seedigation, research was conducted in 1986 and 1987 at the University of Nebraska Agricultural Research and Development Center near Mead, NE. The predominant soil type at the Center is Sharpsburg silty clay loam; Fillmore silty clay loam is found in scattered areas. Slope within the research site is 0 to 3%.

Experimental Design

Three replications of split plots with a randomized complete block design were used to compare the performance of crops that were seedigated and conventionally planted. A grain sorghum, wheat, soybean rotation was studied where seedigation and conventional planting were compared for each crop in the rotation. Relay cropping was also compared to annual cropping for wheat and soybeans. The experimental plot layout for one replication is shown in figure 1. There were seven main plots that were split in various ways during the experiment. The main plots were 0.29 ha (0.7 ac) in size.

In the spring of 1986, there were four treatments on the seven main plots: seedigated grain sorghum, conventionally planted grain sorghum, fallow, and conventionally planted soybeans. The seedigation main plots were split into two subplots where the seeds were incorporated after seedigation by light disking and where the seeds were left as placed with seedigation, i.e. not incorporated. To compare relay and annual cropping, two seedigation, two conventionally planted, and two fallow main plots were necessary.

Winter wheat was grown on five of the seven main plots starting in the fall of 1986 (fig. 1). One main plot that had been fallowed in the spring was drilled to wheat in the fall. Four other plots were seedigated. The relay wheat crop was seedigated into one plot of seedigated and one plot of conventionally planted grain sorghum before the grain sorghum was harvested in the fall. Wheat also was seedigated into one plot that was fallowed in the spring of 1986 and into the plot that was conventionally planted to soybeans. Two plots planted in grain sorghum in the spring

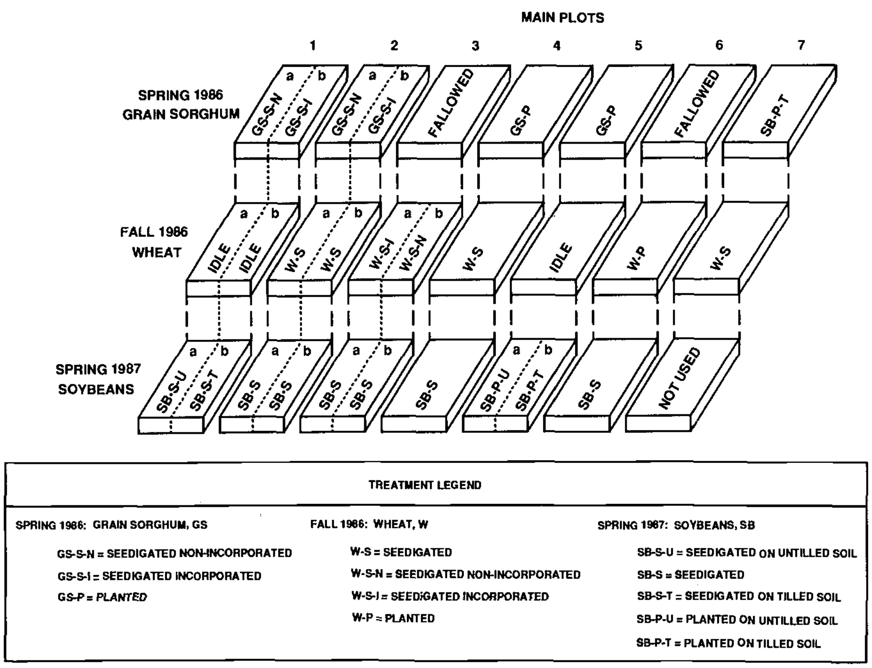

Figure 1–Crop rotation treatment sequence. Numbers signify main plots and small letters denote split plots.

were not seedigated and remained idle during the winter of 1986-1987.

Soybeans were seedigated into five plots in the spring of 1987 (fig. 1). Of the two remaining plots, one was planted to soybeans and one was not used during the summer of 1987. The two plots that were idle during the winter of 1986 were split in the spring of 1987. Half of each plot was tilled prior to both planting and seedigating; the other half was not tilled.

Cultural Practices

The treatments were located between the eighth and ninth tower of a ten tower center pivot irrigation system.

Grain Sorghum Study

To prepare the experimental plots, soybean residue from the previous year was incorporated in late April and mid-May of 1986 with two tandem diskings. Anhydrous ammonia was applied in late April at a rate of 107 kg/ha of N (96 lb/ac). A field cultivator was used to incorporate the herbicide, Igran 80W at a rate of 2.8 kg/ha (2.5 lbs/ac) prior to planting.

Grain sorghum was surface-planted on 30 May 1986 at a seeding rate of 7.9 kg/ha (7.1 lbs/ac). Grain sorghum was seedigated the same day at a rate of 10.3 kg/ha (9.2 lbs/ac). Pioneer 8333 grain sorghum was used throughout the experiment.

Half of the seedigated plots were tandem disked on May 31 to incorporate the seed 2.5 to 3.8 cm (1-1.5 in.) deep. A depth of 3.3 mm (0.13 in.) of water was applied to all plots every nine hours to promote germination. The pivot operated continuously for nine days until the non-incorporated seed developed a root that penetrated the soil surface.

Conventionally planted treatments were cultivated four weeks after planting. The pre-plant herbicide was the only weed control used on the seedigated plots. Plant stand, plant characteristics, and weed populations were measured two and four weeks after planting and prior to harvest on all plots. Areas within the plots were harvested by hand to determine crop yield on 25 October 1986.

Wheat Study

Areas that were fallowed in the summer of 1986 were tandem disked twice during the summer. A field cultivator was used to prepare the seedbed prior to seeding. Designated plots were conventionally drilled on 26 September 1986 using a seeding rate of 82 kg/ha (73 lbs/ac). Heavy rains delayed seedigation until 29 September. The seedigated plots were seeded at a rate of 107 kg/ha (95 lbs/ac). Half of the seedigated plots were incorporated with a tandem disk on 1 October. Rain continued for several days after incorporation which promoted rapid seed germination. The variety of wheat used during the study was Arkan.

Plant population was counted four weeks after seeding and prior to harvest. The number of tillers per plant were counted prior to harvest. Random subplots were harvested by hand on 30 June 1987.

Soybean Study

Residues in areas containing grain sorghum residue without interseeded wheat were shredded prior to planting. The tilled plots in the spring of 1987 were tandem-disked twice to incorporate residue. A tank mixture of Prowl and Sencor herbicide was incorporated with a field cultivator the same day as planting on the tilled plots. The application rate was 2.3 L/ha (1 qt/ac) of Prowl and 0.45 kg/ha (0.4 lb/ac) of Sencor. Untilled plots were sprayed the same day with 2.3 L/ha (1 qt/ac) of Roundup followed with a tank mixture of Lasso and Sencor at 7.0 L/ha (3 qt/ac) and 0.67 kg/ha (0.6 lb/ac), respectively.

Two planting dates were used for the soybean study. The first date was the optimal planting time for annual cropping soybeans. These plots were seeded using a conventional planter and seedigation on the plots that were not planted to wheat in the fall of 1986. Soybeans were surface planted on 19 May 1987; seedigation was completed on 21 May for the tilled and untilled annual cropping plots. Soybeans were seedigated on 8 June for relay cropping soybeans into standing wheat. This was three weeks prior to wheat harvest.

The seeding rate for all seedigation treatments was 124 kg/ha (110 lb/ac) compared to 66 kg/ha (59 lb/ac) for conventional planting. To promote germination on the annual cropping plots, 6 mm (0.25 in.) of water was applied every 18 h for 12 days. The same daily rate of water was applied for 8 days on the relay cropping treatments. A semi-draft variety of soybeans named Hoyt was used.

The herbicide Poast and crop oil were applied in mid-June at a rate of 1.72 L/ha (1 pt/ac) to control grass on the seedigated plots that were not tilled prior to seeding. Conventionally planted soybeans were cultivated in late June and mid-July. All seedigated plots and untilled conventionally planted plots were rope wicked with a 33 percent concentration of Roundup periodically in the latter half of the growing season to help control weeds.

Plant population was determined three weeks after seeding and prior to harvest. Plant characteristics were measured prior to harvest. All plots were mechanically harvested. Harvest loss was calculated by counting the number of seeds on the ground in a small area.

Planting Equipment

Grain sorghum and soybeans were surface planted with a 6-row, John Deere 7000 Max-Emerge. The row spacing was 91 cm (36 in.), planting depth was 25 to 38 mm (1-1.5 in.), and speed of travel was 8.9 km/h (5.5 mph). A John Deere grain drill with 150 mm (6 in.) spacing was used for conventional wheat. Seeding depth was 25 mm (1 in.) while travel speed was 8.9 km/h (5.5 mph).

A Valmont Industries auxiliary pipeline system was used to seed the seedigated treatments. The auxiliary pipeline system is composed of a 63 mm (2.5 in.) black plastic water line and sixteen 80 ELA Rainbird sprinklers spaced 25 m (80 ft) apart. The auxiliary system was attached to an existing center pivot. A micro-processor controlled the timing sequence of the seedigation sprinklers. Sprinklers between the 7th and 10th towers were the only sprinklers activated during the study.

A 1.8 m^3 (50 bu) seed storage hopper located at the pivot point was used to meter and inject the seed and water mixture into the auxiliary pipeline. Seed from the storage hopper was metered by a chain driven metering wheel located below the seed hopper. The wheel was propelled by a hydraulic motor operated by a tractor's hydraulic system.

The speed of the metering wheel was controlled with a hydraulic flow control valve. The seed application depends on the rotational speed of the metering wheel and the travel speed of the last drive unit of the center pivot.

Metered seed dropped into a venturi located within a 1.4 m^3 (360 gal) water reservoir. The swirling action within the venturi mixed the seed and water. Water in the reservoir was supplied by a hose connected to the main water supply for the center pivot. The reservoir supplied water for the auxiliary pipeline.

The seed and water mixture was pressurized to approximately 690 kPa (100 psi) by two 135 mm (5.3 in.) centrifugal pumps. The pumps were installed in series and driven by a tractor PTO. The pressurized seed and water mixture was injected into the auxiliary pipeline and traveled to the activated sprinkler where the seed and water mixture was distributed.

Results and Discussion

Monthly precipitation and average monthly temperature for the two years of the study are compared to the long-term in figure 2. Results show that both 1986 and 1987 were slightly warmer in the spring and cooler in autumn than the long-term average temperature. Early spring rain exceeded the long-term average in 1986, while rain during April and May was below normal. The late summer and early autumn precipitation was much higher than normal in 1986. Precipitation amounts in 1987 are more difficult to qualify. The months of March, May, and August were substantially wetter than normal, while April, June, September, and October were considerably drier than normal.

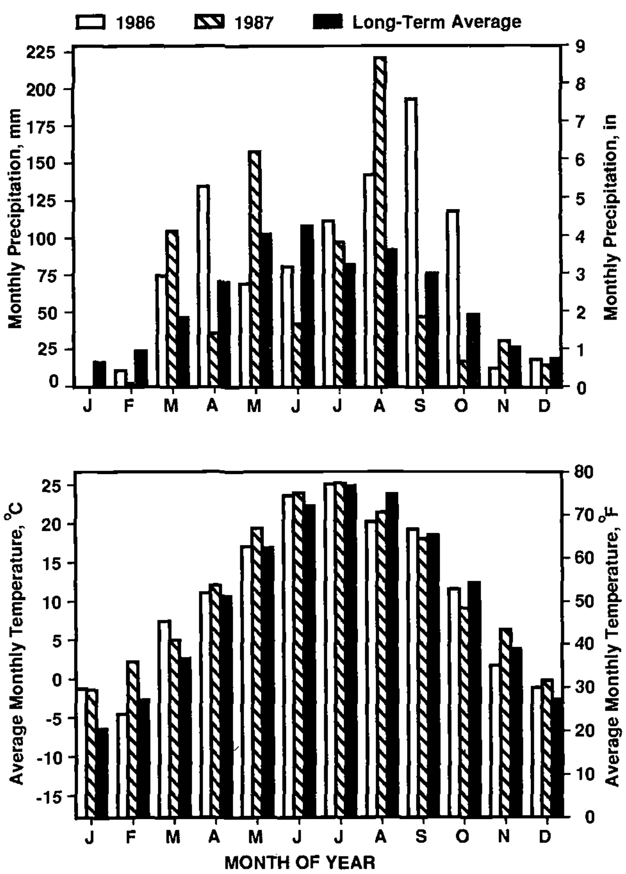

Figure 2–Precipitation and temperature for the two years of study compared to the long-term average for the area.

Comparison of Planting Method

The mean seeding rate, seeding density, germination and grain yield for crops that were conventionally planted and seedigated into fallow conditions are compared in Table 1. Results for the seedigated crops are the average of the plots where seeds were incorporated and plots where seeds were not incorporated.

Germination and grain yield were higher for conventionally planted crops in all cases. The differences in germination were significant for all crops. However, the grain yield differences was only significant for soybeans.

Increasing the seeding rate for seedigation helped compensate for lower germination rates and provided for similar plant densities compared to conventional planting for grain sorghum and wheat. Both the grain sorghum and wheat tillered extensively in areas of low plant density (fig. 3). Wheat and grain sorghum heads were also larger in areas of low plant density. These factors, along with other undetermined conditions, allowed wheat and grain sorghum to compensate for low germination rates and to produce yields that were about the same as for conventional planting. The germination rate of seedigated soybeans was so low that crop yields were severely reduced. The low population of soybeans led to severe weed competition.

Broadleaf weeds were a problem in seedigated grain sorghum averaging 3 weeds/m^2 (2.8 weeds/yd^2) while no weeds were found in the conventionally planted plots. Grasses were also more of a problem in seedigated plots. Herbicide selection was limited by the plan to relay crop wheat into grain sorghum using seedigation. Herbicide carryover and the potential for dissolving herbicide protectant coatings while seedigating were special concerns. The herbicide selected, terbutryn, had a short life with little carryover. The herbicide was applied the day before planting. Grain sorghum would normally develop a full crop canopy by the time the herbicide became ineffective. However, the soil surface was not completely

TABLE 1. Mean performance of crops conventionally planted and seedigated into fallow conditions*

	Seeding rate		Seeding density (1000's of seeds per)		Germination	Grain yield†	
Crop	kg/ha	lb/ac	ha	ac	%	Mg/ha	bu/ac
Grain Sorghum:							
Planted	8 2	7.3	261	106	83a	7.5a	119a
Seedigated	10.6	9.5	340	138	64b	6 8a	108a
Wheat:							
Drilled	82	73	2,920	1,180	94a	4.5a	67a
Seedigated	106	94	3,800	1,540	87b	3.9a	59a
Soybeans:							
Tilled Soil:							
Planted	66	59	412	167	97a	3 5a	50a
Seedigated	123	110	770	312	50b	2 3b	33b
Untilled Soil:							
Planted	66	59	412	167	95a	3.5a	51a
Seedigated	123	110	770	312	18c	1 5c	23c

* Values within any column followed by the same letter for the same crop are not significantly different at the 0 5 probability level

† All yields are expressed for 15% moisture content on a wet weight basis.

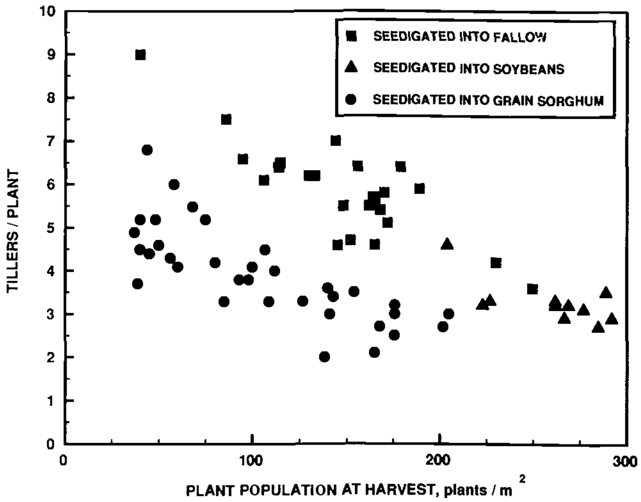

Figure 3–Tiller growth in response to harvest population of wheat.

covered by the grain sorghum canopy in the seedigated treatment and higher weed populations resulted.

The ultimate plant density of wheat varied more than represented by the germination and seeding rates shown in Table 1. Wheat that was seedigated appeared to be more sensitive to winter kill than drilled wheat. Approximately 94% of the conventionally planted wheat seeds germinated and 77% survived the winter. For seedigation, 87% of the seeds germinated, but only 44% survived the winter. These data suggest that wheat varieties used for seedigation should be very winter hardy.

Seedigation of soybeans produced very poor results. The germination and yield for the seedigated plots were very low compared to planted soybeans. Apparently, seedigating into tilled soil allowed for better seed-soil contact and higher germination than for the untilled plots. However, the germination and yield were low for either seedigation practice.

The low plant populations in the seedigated soybean plots led to both broadleaf and grassy weed problems that required post emergence control. A high harvest loss also occurred within the seedigated plots. The shorter and bushier plants lacked enough plant material to feed into the combine. Some plants fell out of the header. Seeds on the soil were counted to determine the harvest loss. The harvested yield and harvest loss were added to give the values in Table 1. The seedigated treatment that was not tilled had the highest harvest loss at 0.9 Mg/ha (13 bu/ac). Low germination rates, weed control problems, and low yields occurred with soybean seedigation. Conventional planting was clearly the best method to plant soybeans for this study.

Effect of Incorporation

Incorporating grain sorghum or wheat following seedigation did not improve crop yield or seed germination (Table 2). Germination for incorporated plots was slightly higher for grain sorghum but lower for wheat. Crop yield showed exactly the opposite trend. The only statistically significant difference for incorporation was for germination of wheat. In that case, incorporation actually reduced germination. Based on these results, incorporating seeds with shallow disking of areas that were tilled prior to seedigation seems to be unwarranted.

TABLE 2. Mean germination rate and yield for crops that were incorporated and not incorporated following seedigation*

	Germination	Grain yield†	
Crop	%	Mg/ha	bu/ac
Grain Sorghum:			
Incorporated	70a	6.7a	106a
Not Incorporated	58a	7.0a	111a
Wheat:			
Incorporated	84a	4.1a	61a
Not Incorporated	89b	3.8a	56a

* Values followed by the same letter for the same crop are not significantly different at the 0.05 probability level.

† All yield data are expressed for 15% moisture content on a wet weight basis.

Comparison of Relay Cropping

Seedigation offers the potential to relay crop wheat into grain sorghum or soybeans. Performance of wheat drilled into fallowed soil, seedigated into growing soybean and seedigated into growing grain sorghum are summarized in Table 3. These results show that there were no statistically significant differences between drilled wheat and wheat seedigated into soybeans.

Wheat seedigated into growing grain sorghum did much worse than the drilled wheat or wheat seedigated into soybeans. Yields for wheat seedigated into grain sorghum were approximately one-third of the yield with the other two treatments.

A major reason for the poor yield was the low harvest population of the wheat seedigated into grain sorghum. Based on visual observations, we suspect that winter kill was the principal problem. The dense grain sorghum canopy limited the ability of wheat seedlings to establish before a killing frost. The wheat germinated well but seedlings were elongated and spindly with the root system lying on the soil surface. The wheat had not started to tiller before a killing frost. Approximately half of the seedlings that germinated died before spring. Increasing amounts of grain sorghum residue substantially reduced wheat survival (fig. 4).

TABLE 3. Mean performance of wheat for annual and relay cropping*

Cropping system	Residue present at time of planting		Ratio of harvest population to seeded population	Grain yield	
	Mg/ha	lb/ac	%	Mg/ha	bu/ac
Annual wheat drilled into fallow	–	–	77a	4.5a	67a
Wheat relay cropped into soybeans	–	–	70a	4.5a	67a
Wheat relay cropped into sorghum with:					
- light residue	3.9	3470	36b	1.6b	24b
- medium residue	4.3	3810	25c	1.4b	20b
- heavy residue	5.4	4820	23c	1.6b	24b

* Values in a column followed by the same letter are not significantly different at the 0.05 probability level.

Wheat relay cropping into soybeans did not experience the low plant survival as wheat seedigated into grain sorghum. The soybeans were fully mature and had begun to drop leaves prior to seedigating the wheat. The wheat was not hampered by a dense crop canopy, thus there was ample sunlight to promote plant growth. Wheat interseeded into soybeans and conventionally drilled had both started to tiller before a killing frost.

Prior to wheat harvest, the number of tillers per plant were counted within each subplot. An inverse relationship was found between the number of tillers and plant population. Conventionally planted wheat produced more tillers at the same population than the relay crop treatments (fig. 3).

The second test of relay cropping involved soybeans in the spring of 1987. Soybeans that were seedigated into growing wheat had very low germination rates (Table 4). Seedigation of soybeans into fallow conditions also had very low germination rates and yield (Table 1). Seedigating relay cropped soybeans into wheat did not improve germination.

Soybeans relay cropped into wheat developed elongated and spindly stems during the first two weeks of growth. Grasshoppers also migrated into the wheat where the relay cropped soybeans were growing. When the wheat was harvested, virtually all soybean seedlings had been destroyed. The grasshoppers did not damage the other treatments that were more mature. Thus, yield data were not collected on the relay crop soybean treatments. Plant populations were quite low in these plots anyway.

Summary and Conclusions

Seedigation of wheat and grain sorghum appears to be feasible. The germination rate of seedigated grain sorghum and wheat were lower than for conventional planting. To compensate for a potentially lower plant population, the seeding rate of each crop was increased by 30% above that for conventional planting. When the seeding rate was increased, the grain yield for seedigation was not statistically different than for conventionally planted crops.

Seedigation of soybeans appears to have less potential. Seedigated soybeans had very low germination rates. Grain yield for seedigated soybeans were significantly less than for conventional planting even though the seeding rate for seedigation was double that for conventional planting. Seedigation of soybeans into growing wheat was even less successful.

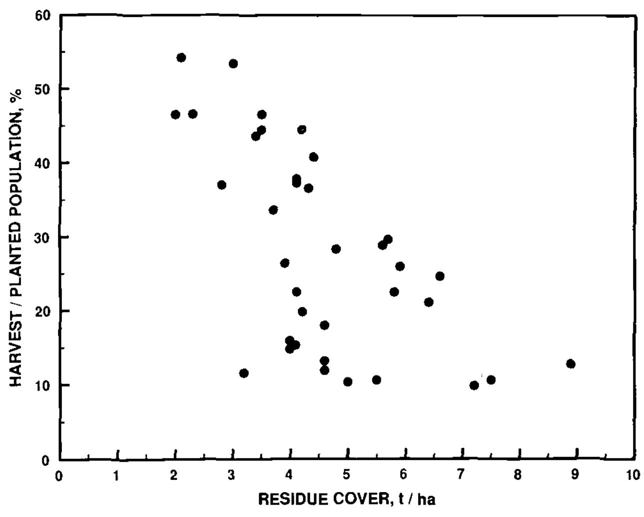

Figure 4–Effect of the amount of grain sorghum residue on the harvest population of relay cropped wheat.

TABLE 4. Mean performance of soybeans for annual and relay cropping

Cropping system	Time required for germination	Germination*
	days	%
Planted into tilled soil	5	97a
Planted into untilled soil	6	94a
Seedigated into growing wheat that:		
- was conventionally planted	8	25b
- was seedigated	7	27b

* Values in the same column followed by the same letter are not significantly different at the 0.05 probability level.

Experiments were conducted to determine if incorporating seeds by shallow disking after seedigation was beneficial. The plots used for this test had been tilled prior to seedigation. Results showed that incorporation was not beneficial. Germination rates and yields were not significantly different in most cases. The only significant difference occurred where incorporation of wheat actually reduced germination, but did not affect yield.

Our results with relay cropping wheat into soybeans was very encouraging. The germination and yield for seedigated wheat was essentially the same as wheat planted into fallow conditions. However, seedigating into growing grain sorghum was less successful. The wheat germinated fine, but developed spindly growth with exposed roots. Wheat seedigated into the grain sorghum experienced substantial winter kill that limited its potential. Increasing amounts of grain sorghum plant material decreased wheat survival.

Results of these experiments are based on the timing and cultural practices we employed plus the environmental conditions that occurred. Surface seeding research has indicated that success can greatly depend on each of these factors. Continued research is needed to develop the best management system for seedigation. Seedigation appears to offer some additional opportunities depending on the crop selected and management objective.

Acknowledgment. The authors thank Valmont Industries for partial support of this research.

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